

Reply to Comment on “New formulas for the (-2) moment of the photo-absorption cross section, σ_{-2} ”

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In the Comment to my paper [1], von Neumann-Cosel suggests that the low-energy contribution to σ_{-2} caused by the pygmy dipole resonance (PDR) should provide a systematic upward correction of the order of 5-10%. The author additionally performs a free fit to σ_{-2} data from polarizability (^{120}Sn [2] and ^{208}Pb [3]), photoneutron cross section (^{68}Ni [4, 5]), and total nuclear photoabsorption (^{12}C , ^{16}O , ^{27}Al and ^{40}Ca [6]) studies. Different volume, S_v , and surface-to-volume, S_s/S_v , coefficients of the symmetry energy to the ones given by Tian and collaborators [7] are extracted. According to von Neumann-Cosel, the coefficients from the free fit “may be better suited”.

I agree with the author that, because of the low-energy PDR contribution, a systematic upward correction to σ_{-2} can be expected in nuclei with neutron excess considering the E_γ^{-2} weighting of σ_{-2} . However, it is premature to claim a general PDR contribution to σ_{-2} based on four measurements only (inelastic proton scattering at relativistic energies of ^{120}Sn [2], ^{208}Pb [3] and ^{90}Zr [8], and a selected photon scattering measurement in ^{138}Ba [9]). Moreover, the author provides estimates for only two measurements (^{120}Sn and ^{208}Pb). Additional measurements of the PDR contribution for a broader range of nuclei with neutron excess are clearly needed to deduce a systematic effect.

Furthermore, I see several arguments against the symmetry energy parameters extracted by von Neumann-Cosel.

1) The author uses the nuclear photoabsorption data from five nuclei (^{12}C , ^{16}O , ^{27}Al , ^{40}Ca [6, 10] and ^{68}Ni [4, 5]) to perform a free fit to the S_v and S_s/S_v variables in Eq.[12] of my paper [1]. He claims that his resulting parameters “may be better suited” to the σ_{-2} trend partly because four data points (^{12}C , ^{16}O , ^{27}Al , ^{40}Ca [6, 10]) include both photoproton and photoneutron cross sections above 10 MeV. These four data points are derived from a single total nuclear photoabsorption study by Ahrens and co-workers in 1975, which used bremsstrahlung photon beams. As pointed out by Bergere [11], care must be taken concerning this method, because it has the drawback of large non-nuclear contributions (e.g., Compton scattering, pair production, dead

times) which are several tens of times larger than the total nuclear photoabsorption cross section [11]. Monte-Carlo simulations should be conducted to calculate the error for each non-nuclear contribution. Such simulations are not evident in Ref. [6]. Therefore, the less than 0.1% error from non-nuclear effects claimed by Ahrens and collaborators is questionable. Moreover, if these measurements were as powerful and precise, one can only wonder why they were not verified and applied for the photon energy range of interest to σ_{-2} since.

In addition, the ^{68}Ni data point [4, 5] in Fig. 1 of the Comment only includes (γ, n) and $(\gamma, 2n)$ photoneutron cross sections and does not account for other neutron decay channels and photoproton contributions. More relevantly, most of the existing information on photoabsorption cross sections arise from stable nuclei, i.e., we know very little on how unbound nuclei polarize. Hence, the ^{68}Ni data point should not be included in the free fit.

2) In Ref. [1], I used two independent methods to derive σ_{-2} : 1) from a fit to the extensive photoneutron compilation published in 1988 [12], which includes data from the preferred method of monochromatic photon beams generated by in-flight annihilation of positrons¹, and shows overall agreement and consistency between measurements done at Livermore, Giessen, Saclay and other laboratories, and 2) from the mass dependence of the symmetry energy extracted from a global fit to the binding energies of isobaric nuclei with $A \geq 10$ [7] given by the 2012 mass evaluation [13]. These two predicted trends smoothly converge with the σ_{-2} data [12] above $A \gtrsim 70$, in agreement with the dominant photoneutron cross sections for heavy nuclei. No consistency in the photoneutron data is observed for lighter nuclei, which highlights the necessity for systematic studies of photoproton cross sections for $A \lesssim 70$ nuclei. This should, preferably, be done in direct and simultaneous measurements of the partial photoneutron and photoproton cross sections, crucial to obtain reliable total photonuclear cross sections, as described in Ref. [14].

3) Figure 1 shows σ_{-2} plots for the different sets of symmetry energy parameters discussed in this work. Von

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¹One main advantage of this technique over bremsstrahlung photon beams is the direct and simultaneous measurements of the partial photoneutron cross sections which are in competition in the GDR region.

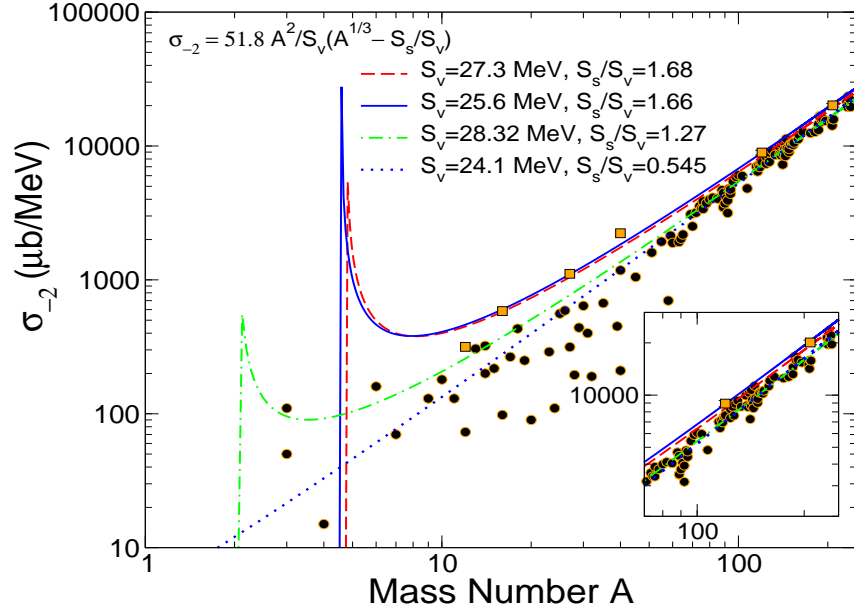


FIG. 1. (Color online) σ_{-2} plots for different sets of $(S_v, S_s/S_v)$ symmetry-energy parameters discussed in this work. The σ_{-2} data *vs* A on a log-log scale from the 1988 photo-neutron cross-section evaluation (circles) [12] and from data provided in the Comment (squares) are shown for comparison. From the data presented in Fig. [1] of the Comment, the ^{68}Ni data point has been removed (see text for explanation) and the ^{40}Ca data point has not been lowered from Ref. [6].

Neumann-Cosel shows that, when omitting the ^{12}C data point, his analysis provides a better fit to the available data with symmetry-energy parameters ($S_v = 25.6(8)$ MeV, $S_s/S_v = 1.66(5)$) similar to those calculated in Ref. [15] ($S_v = 27.3$ MeV, $S_s/S_v = 1.68$). One should at least mention the drawback of these theoretical parameters which include the Coulomb interaction of protons but do not imply a neutron skin, later precisely measured in ^{208}Pb by Tamii and collaborators [3]. Considering a neutron skin has a dramatic effect on the calculated surface-to-volume ratio ($S_v = 24.1$ MeV, $S_s/S_v = 0.545$) [15]. It is true that the latter parameters fail to describe the σ_{-2} data for light nuclei, but it seems to work where it is intended to, i.e., for heavy nuclei, where the excess neutrons can form a skin against a $N \approx Z$ core. In fact, the calculated σ_{-2} trend implying a neutron skin ($S_v = 24.1$ MeV, $S_s/S_v = 0.545$) also converges with the photoneutron data [12] and with Eq. [14] ($S_v = 28.32$ MeV, $S_s/S_v = 1.27$) in Ref. [1] for $A \gtrsim 70$, as clearly shown in the inset of Fig. 1.

In conclusion, I agree with the relevance of the PDR contribution at low energies [12], a contribution that remains to be quantified for many heavy nuclei with neutron excess, but disagree with the statement that the different volume and surface-to-volume coefficients of the symmetry energy extracted from a free fit in von Neumann-Cosel's Comment are better suited than the ones chosen in my paper [7]. The fact of the matter is

that additional data are vital to pin down the mass dependence of σ_{-2} and the symmetry energy, especially for nuclei below $A \approx 70$. The author acknowledges funding support by the South African National Research Foundation (NRF) under Grant 93500.

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